

PATENT

ATTORNEY DOCKET NO.: 2001/07

UNITED STATES PATENT APPLICATION

OF

DOUGLAS DUANE ROTH

FOR

NONWOVEN BLEND WITH ELECTRET FIBER

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2

NONWOVEN BLEND WITH ELECTRET FIBER

BACKGROUND OF THE INVENTION

1) Field of the Invention:

The present invention relates to a blend of electret fibers and dissimilar non-electret fibers useful for making nonwoven webs. The nonwoven webs are used in making filter fabric and particularly air filter fabric. In particular, the present invention relates to a blend of electret based fibers having one or more charge control agents (CCA) with dissimilar fibers having no CCA. More specifically, the present invention concerns a nonwoven web useful in air filters comprising fibers of polypropylene with one or more charge control agents and polyethylene terephthalate fibers having no CCA.

2) Prior Art

Use of polypropylene electret fibers for filter fabric has been known since the Naval Research Laboratories published Report No. 4364 on May 25, 1954, entitled "Manufacturer of Superfine Organic Fibers" by Van Wente et al. Since that time, many patents have issued on electret fibers and other filter media fabric.

Two types of charges are responsible for the electric fields within the fabric, namely: polarization charges and free (or coulomb) charges. Polarization charges result from the displacement of positive and negative charges within the fiber, e.g., preferential orientation of dipolar bonds. An example of polarization charges is the charge resulting from solidification of the molten fiber in the presence of a strong electric field. The charge polarization produces dipole fields that may be relatively strong at the fiber surface, but decrease rapidly with increased distance from the fiber surface.

Free or coulomb charges generate longer-range forces due to an excess or deficiency of electrons over a substantial length of fiber. These coulomb fields are typically better dust collectors than polarization fields. It is possible to generate "islands" of isolated charges at various locations within the fabric. Additives to the polymer may improve coulomb charge storage in a fiber. These additives are generally known as charge control agents (CCA).

Triboelectric charging generates free charges on the fiber, and results whenever two dissimilar materials are brought into contact, then separated. The amount of charge transfer, and the direction of the electron transfer both depend on the material, their temperature, humidity, etc. Triboelectric charging offers the possibility of a continual source of charge imbalance in fibers, e.g., by mixing fiber materials that have a strong natural tendency to transfer charges to each other. In order for the charge separation to produce useful electric fields, it is important that at least one of the members be a sufficiently good insulator to maintain its charged state for the required period of time (several months to several years).

Knowing the material to be filtered is important in determining the effectiveness of the filter web. For example, common house dust composed of human skin, hair and fur from animals is usually positive in charge. Accordingly, having a filter with areas of negative charge will enhance the filtration of these particles in that opposite charges attract one another. Conversely, if rubber dust is being separated, it generally possesses a negative charge and having areas in the filter that are positively charged is desirable. It is not necessary for the filtered particles to possess any free charge in order for an electret filter to attract them. If the particles can be polarized by the electric field around the fiber, the charge imbalance can generate an attraction. The stronger the electric field, the more effective is the filtration.

U.S. Patent No. 5,726,107 to Dahringer et al. discloses fabrics made of polymer electret fibers having 0.01 to 30% by weight of at least one charge control agent. This patent lists many classes of CCA compatible with polyolefin polymers.

Blends of electret fibers with non-electret fibers are known and disclosed in U.S. Patent No. 5,871,845 to Dahringer et al. Column 14, lines 9-50 state that electret yarns can be present as mixed yarns with other synthetic fibers or natural fibers. However, as explained below, the examples of this patent use similar fibers for both the electret and non-electret fibers.

U.S. Patent '845 is specifically directed to polyethylene terephthalate (PET) electret fibers (e-PET) using the same CCA as the present invention. It discloses the use of these e-PET fibers with regular PET fibers. In all examples, 20 percent bicomponent (copolyester / polyester) was employed. In Table 1, Sample 1 was e-PET. Sample 2 was a 50/50 blend of e-PET and PET. Sample 3 was PET alone. The degree of separation $T(x)$ was measured to show the filtration efficiency. From this data it is clear that a 50/50 blend (Sample 2) has a $T(x)$ value midway between e-PET and PET. This indicates that the rule of mixtures holds.

Table 1

Particle Size	$T(x)$		
	Sample 1 e-PET	Sample 2 e-PET/PET	Sample 3 PET
0.3	0.81	0.71	0.62
0.5	0.85	0.77	0.70
1.0	0.89	0.82	0.77

While the above fibers were formed by melt spinning, it is also known to form the fibers by melt blowing.

Lastly, several methods are known to charge electret fibers such as corona charging, triboelectric charging and inductive charging. These methods provide differing relative amounts of free charge and polarization charge.

U.S. Patent No. 4,874,399 to Reed et al. discloses a melt blown blend of electret fibers comprising poly (4-methyl-1-pentene) and other polyolefin fibers that can accept a filtration-enhancing electrostatic charge and sustain that electret filtration enhancement in the presence of oily aerosols.

U.S. Patent No. 5,401,466 to Tsai et al. discloses a charging process in which a web containing electrostatic fibers traverses through an electrostatic field and the fibers accept and sustain a filtration enhancing electrostatic charge. Then the web traverses through another charging field where the polarity of the field is reversed. This is called the Tantret™ process.

U.S. Patent 5,558,809 to Groh et al. discloses the use of additives to produce polymer electrets. In particular, this reference discloses the use of a polymer electret, CCA, and an arylsulfide compound and an azochromium complex. Additionally, Groh et al. teach that electret fibers can be charged using a corona or triboelectric process.

To determine filter efficiency, the properties of the polymer, the structure of the filter media, and the determination of the electrostatic charge effectiveness are important considerations. Among these, electrical conductivity is believed to be the most important in affecting the performance of the charged fibers. Subsequently, there is a continual need for improving electret fibers by improving the electrostatic charge effectiveness and particularly by increasing the electrical resistivity of the electret fibers.

SUMMARY OF THE INVENTION

The present invention relates to a blend of 15-97 weight percent electret fibers and 3-85 percent by weight dissimilar non-electret fibers using dry laid blending techniques. The electret fibers incorporate 0.05 to 30 weight percent CCA. Optionally, at least about 3 percent by weight of the fiber blend is bicomponent fibers having a low melting point component to bond the blend into a unitary nonwoven structure.

In the broadest sense, the present invention comprises a blend of 15-97 weight percent electret fibers, and 3-85 percent by weight dissimilar non-electret fibers, said electret fibers having 0.05 to 30 weight percent CCA.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 is a graph of filter efficiency versus percent electret fibers for uncharged webs.

Figure 2 is a graph of filter efficiency versus percent electret fibers for charged webs.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Suitable CCA of the present invention are selected from the class of CCA set forth in U.S. Patent 5,726,107 to Dahringer et al. and the specification of this application is hereby incorporated into this specification in its entirety. These CCA are chosen from the group consisting of triphenylmethanes; ammonium and immonium compounds; fluorinated ammonium and immonium compounds; bis-cationic acid amides; polymeric ammonium compounds; diallylammonium compounds; arylsulfide derivatives; phenol derivatives; phosphonium compounds and fluorinated phosphonium compounds; calix(n)arenes; metal complex compounds; benzimidazolones; and azines, thiazines or oxazines which are listed in the Color Index as Pigments, Solvent Dyes, Basic Dyes or Acid Dyes. Additionally, suitable CCA of the present invention can be those sold under the brand names 'Copy Charge' or 'Copy Blue' from Clariant Corporation.

It has been determined that the COPY BLUE PR enhances the negative charge capability of the electret, while the COPY CHARGE NY VP 2351 enhances the positive charge capability of the electret. Utilizing either of these CCA makes a polymer "more negative" or "more positive" within the triboelectric scale. The triboelectric scale is a list

set forth from Nature's Electricity, page 63, by Charles K. Adams, Copyright 1987 hereby incorporated into the specification in its entirety.

The amount of CCA incorporated into the electret is in a range from about 0.05 to 30% by weight based on the weight of the electret fibers. More preferably, the amount of CCA ranges from about 0.1 to about 5% by weight based on the weight of the electret fibers, and most preferably, from about 0.1 to 1.0 % by weight based on the weight of the electret fiber. The CCA can simply be blended with the molten polymer selected for the electret fibers, just prior to extrusion.

Suitable polymers for the electret fiber are polytetrafluoroethylene (Teflon), polyolefin, polyurethane, polyester, polycarbonate, or a mixture of two or more of these. Suitable polyolefins of the present invention are polyethylene, polypropylene, and polybutylene, or mixtures of these. The preferred polyolefin is polypropylene. Suitable polyesters of the present invention are polyethylene terephthalate (PET), polypropylene terephthalate, polybutylene terephthalate, polyethylene naphthalate, polyethylene bibenzoate, or mixtures of two or more of these. The preferred polyester is PET.

The electret fiber may be made from homopolymer or copolymer, or a heterofilament, which is a bicomponent where one component is an electret. Thus the heterofilament may be employed as an inexpensive way to make an electret. For example, the sheath may be CCA filled and the core may be any inexpensive filler material (it is known from the '845 patent that CCA is less effective the further it is from the particles to be filtered, so CCA not on the surface of the fiber may be of diminished value).

The dissimilar non-electret fiber may be any common synthetic fiber so long as it is not the same polymer (preferably not even the same class of polymer) as the electret synthetic fiber polymer. Suitable dissimilar non-electret fibers that can be employed are polyolefin, polyacrylates, polyacrylonitrile, polystyrene, fluoropolymers,

polytetrafluoroethylene (otherwise known as Teflon), polyesters, such as polyethylene terephthalate, copolyesters, polyurethane, polycarbonates, polyamides, polyimides, polyetherketones, polyacetals, or a mixture of two or more of these. Therefore the dissimilar fiber could be homopolymer, or copolymer.

The electret fibers and the dissimilar non-electret fibers may be blended together by any dry laid processes known to those skilled in the art, such as air laying, carding, garneting, or random carding. By convention in the art, small letter 'e' before a polymer means that the polymer is the electret polymer or fiber. Suitable blends are e – polypropylene/ polyester; e – polyester/ nylon; e – polyurethane/ polyacrylates, to name just a few. Other suitable blends can comprise mixtures of electret fibers and/or mixtures of dissimilar fibers.

The filter web can be bonded by mechanical, chemical or thermal processes. Mechanical bonding uses entanglements introduced by needle punching or hydroentangling. Chemical bonding uses adhesives such as latex resins, or hot melt adhesives. Thermal bonding utilizes low melt point fibers melted in an oven (hot air, radiant or microwave), on heated calender roll(s), or by ultrasonic energy.

The preferred binder systems of the present invention are conventional latex systems, hot melt adhesives, or thermal bonding fibers, or a mixture of these. Conventional latex systems such as styrene-butadiene copolymer, acrylate, and polyvinyl acetate systems, as well as mixtures of these are well known. When a conventional latex system is employed with the present invention, the amount of binder may range from 5 – 60 % by weight of the web. Hot melt adhesives are generally solid powder materials, non-latex paste, and/or liquid compositions well known to those in the art. Thermal bonding comprises conventional low melt fibers, bicomponent fibers, or a mixture of these, which are melted as stated previously, and cooled to solidify the melt, thus bonding the blend of fibers. Conventional low melt fibers can be polyolefins, for example, and in particular linear low-density polyethylene.

Bicomponent fibers can be of the type in which the low melting point portion is adjacent to the high melting point portion such as a side-by-side configuration, or in a sheath-core configuration wherein the sheath is the lower melting component and the core is the higher melting component. It is contemplated that the web of the present invention will comprise between 3 and 50 % by weight thermal bonding fiber, such as bicomponent bonding fiber. This optimum amount of thermal bonding fiber is deemed to be adequate to bond the web into a unitary structure.

Suitable bicomponent fibers have a denier of between about 0.5 – 18 and can comprise polyethylene/polypropylene; polyethylene/polyester (especially polyethylene terephthalate); polypropylene/polyester; copolyester/polyethylene terephthalate, such as polyethylene terephthalate-isophthalate/polyethylene terephthalate; nylon 6/nylon 6,6; and nylon 6/polyethylene terephthalate. Preferably polyethylene/polyester bicomponent fibers are used, especially grafted polyethylene/polyethylene terephthalate, such as linear low-density polyethylene/polyethylene terephthalate. Bicomponent fibers having a denier of between 2 and 6 are the preferred thermal bonding fiber.

Optionally, the electret heterofilament can serve as the binder fiber. The heterofilament could consist of a low melting point component and an electret high melting point component. Alternatively, the low melting component of the heterofilament could function as the electret.

Those skilled in the art realize that that the present invention may be a two component blend or a three component blend. For example, a blend of electrets and dissimilar fibers that are mechanically bonded is a typical two component blend. Another two component blend is when the electret fiber is a heterofilament that also serves as a binder. A typical three component blend comprises electret fiber, dissimilar fiber, and bicomponent fibers as binder. The three component blend is the preferred embodiment.

In the preferred embodiment, once the electret fibers, dissimilar non-electret fibers and bicomponent binder fibers have been selected, these fibers can be typically

blended by any dry laid processes, such as air laid, carding, garneting, or random carding processes conventionally known to those skilled in the art. Subsequent to dry laying, the fibers are heated, thereby melting the low melt component of the bicomponent fibers causing it to run to the intersection of fibers. The fibers are then permitted to cool and the low melting component solidifies, forming a unified filter web. Suitable filter webs have weights in the range of 50 to about 500 grams per square meter, depending upon its use. Typically, the filter web comprises from about 50 to about 100 grams per square meter.

Preferably the electret fibers of the present invention are charged. However, even if no physical charging takes place, triboelectric effects occur and the CCA possesses the ability to attract oppositely charged particles, thus improving the filter efficiency. Introducing the electret fibers (before dry laying/blending, after dry laying/blending, or after bonding into a filter web) to a corona treatment or preferably a Tantret™ process charges the CCA.

The preferred fiber blend of the present invention consists of: polypropylene electret fibers having between 0.1 and 1.0 percent by weight charge control agent; dissimilar non-electret polyester fibers; and bicomponent binder fibers comprising a low melting component and a PET component.

TESTING PROCEDURE

The filter efficiency was measured, both with and without being charged, using a TSI Model 8130 using sodium chloride having a particle size of 0.1 microns and a base velocity of 5.3 centimeters per second.

The denier per filament (dpf) was determined by weighing (in grams) 9000 meters of a filament.

The Example

Six filter webs were made with different fiber blends as well as with different CCA. The fibers were blended, carded, and cross-lapped. In Samples 4 and 6, the fibers were bonded by needle punching. In all other Samples the webs were bonded by the bicomponent fibers. The webs were approximately 85 grams per square meter.

The electret fibers were polypropylene having a dpf of 2.2. The electret fibers of Samples 2-4 contained 0.3 weight % Copy Blue PR, while Samples 5 and 6 contained 0.15 weight % Copy Charge NY VP 2351. The non-electret fibers were PET fibers having a 3 dpf and were about 1.5 inches long. The bicomponent fibers were 35/65 wt. % copolyester/PET sheath-core type about 2 inches long, and comprised about 20% by weight of the filter web when employed. The filter efficiency was measured without charging, and then the fiber was charged and the filter efficiency was measured again. The filter webs were charged by the Tantret™ process. The results are set forth in Table 2 below and graphically shown in Figures 1 and 2.

Table 2 FILTER EFFICIENCY RESULTS

Sample	% Electret Fiber (e-PP)	CCA Type	Filter Efficiency (No Charging)	Filter Efficiency (After Charging)
1	0		1.4	3.5
2	40	Copy Blue	8.8	39.4
3	80	Copy Blue	34.3	62.4
4	100	Copy Blue	27.6	51.8
5	80	Copy Charge	11.2	37.3
6	100	Copy Charge	26.4	59.8

The filter efficiency of samples containing an electret fiber is greatly increased by the charging process due to the creation of very positive charges in some areas of the web and relatively negative charges in other areas. In the case of blends of electret fibers containing charge control agents and non-electret fibers, there is superimposed on this pattern a triboelectric effect. In this example, the electret fibers are polypropylene with CCA and the non-electret fibers are polyester. Polypropylene is more negative in

triboelectric effect relative to polyester. Therefore the Copy Blue additive, which enhances the negative charge capability of the electret fibers, increases the triboelectric difference of the two materials, and increases the triboelectric charging. As noted in the table there is a surprising result when the amount of electret fiber is about 80 percent by weight of the blend, both with no charging and after charging. This filter efficiency is greater than using 100 percent electret fiber. Surprisingly, Figure 2 shows that blend levels of 15 –97 % of electrets are better than the rule of mixtures as predicted by the prior art. The rule of mixtures for charged Copy Blue is the dotted line extending between 0 and 100 % electret fibers. For example, when using 50 % electret fibers, the rule of mixture would predict a filter efficiency of about 25 %, while the present invention yields a result of about 45 %.

On the other hand, when using Copy Charge, which enhances the positive charge capability of the electret, filter efficiency of the blends is still improved (compared with no electrets – Sample 1) but not as great as when using the Copy Blue. The triboelectric difference between the two materials is reduced, which decreases the triboelectric charging effect. This results in a reduction in filter efficiency, which can be seen in Figures 1 and 2.

Thus, it is apparent that there has been provided, in accordance with the invention, an improved filter web and a blend of electret and dissimilar non-electret fibers, that fully satisfy the objects, aims, and advantages set forth above. While the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications, and variations as fall within the spirit and broad scope of the invention.